# MAXIMIZING USER ACCEPTANCE - A SYSTEMS APPROACH (U)

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One of the goals of Human Factors Engineering (HFE) is to insure that newly developed items of clothing and equipment can be worn by the combat infantryman with minimum degradation in performance. An equally important but sometimes overlooked goal is maximizing the probability that troops in the field will accept new items and employ them in the prescribed fashion. These two goals, which might be broadly categorized as "operational suitability" and "user acceptance" respectively, are not mutually exclusive, but the former is often achieved at the expense of the latter. That is to say, failure to adequately consider the user's judgment of and response to item characteristics is often linked with the materiel developer's preoccupation with satisfying a set of required operating characteristics. We consider this problem of operation vs. acceptance as largely an artifact, stemming in part from previous development efforts. Such a dichotomy of emphasis should be avoided whenever possible; in the long run, if the user is not satisfied with an item/system, said item/system will ultimately be rejected through such mechanisms as misuse, disuse, or preoccupation with the development of alternatives/replacements. It is our thesis that this type of situation can be ameliorated through the application of HFE methods which reflect an integrated approach with respect to man-oriented vs. system-oriented evaluative criteria.

A CASE FOR USER ACCEPTANCE. It has often been said, with respect to some undesirable item, that "Complaints disappear when the bullets start to fly." Data gathered by the Army's Wound Data and Munitions Effectiveness Team (WDMET) and reported in GAO Letter Report B-174472 (11) do not wholly support such a contention. They found, for both

the Army and Marine Corps Wounded-in-Action, wounds in the protected area were reduced by about 40% (for all fragmenting munitions) when body armor was worn. The next important point contained in the WDMET analyses relates to the usage rates for body armor, 19% and 72% for Army and Marine Corps respectively. Although these figures can be criticized to some extent with respect to sampling procedures employed, when considered together with debriefing reports of Vietnam veterans regarding use of the armored vest, they do make a case for the fact that a standard, type-classified item deemed operationally suitable was, in fact, rejected by a number of troops in the field. Here, then, is an instance in which lack of user acceptance had serious consequences for the operational efficiency and safety of the combat soldier.

HFE AND THE DESIGN CYCLE. For most items or systems, initial design criteria are formulated during materiel concept investigations and are established through a jointly prepared, formally approved Letter of Agreement (LOA) between the combat developer and the materiel developer. These design criteria are early objectives or characteristics stated in broad bands of performance and, as such, are the user's first indication of what he will accept in the way of item/system design features. Let us pause here to make an important point: the maximum effectiveness of HFE inputs to a design effort occurs when such inputs are made prior to the existence of a piece of hardware. In effect, we are saying that the design criteria from which prototype items are developed should already include strong HFE inputs. During this phase of item development, HFE inputs can most easily be implemented. Later on, when one or more hardware items exist, HFE recommendations for design changes, if considered at all, are apt to require the expenditure of large sums of money and cause unacceptable delays in program schedules.

Once prototype items are available, the HFE effort becomes increasingly focused on the impact of the item/system on the actual performance of the human component. Remember, up to this point, user requirements have been primarily stated in terms of hardware specifications derived from strategic or tactical considerations, while HFE analyses have aimed at determining whether the proposed operation/employment of the item is within established ranges of human capabilities for specific missions/tasks. Let us turn now to some of the problems in HFE analyses which are outgrowths of both development/operation test requirements and the increased user-item interactions.

CONCEPTUAL PROBLEMS IN HFE ANALYSES. The first conceptual problem generated by increasing the user's involvement with the item under

development is one of definition. It now becomes important to define both "user" and "user acceptance." Probably the easiest of these terms to define is the user. By user, we mean simply the combat soldier (infantryman), regardless of rank, grade of MOS, whether engaged in training or in an actual combat situation. User acceptance is a slightly harder term to pin down since it encompasses actions ranging from formal approval via type-classification, through endorsement and deployment by field commanders in MTOE lists, to the enthusiastic reception and usage by the field soldier in the performance of his mission. Though all three types of action reflect some degree of user acceptance, it is the third connotation -- acceptance by troops in the field -- with which we as Human Factors Engineers are ultimately most concerned.

The second conceptual problem is also a matter of definition. The scope, magnitude and direction of an HFE analysis are directly related to the complexity of the item/system being developed. Characteristically, new items slated for eventual use by the combat soldier in the field are developed in relative isolation. That is, early development tends to treat an item as though it were the only one with which the soldier must deal. Anyone who has ever looked at a compilation of actual combat loads for various MOSs has seen one of the more striking consequences of this approach; in many cases the total weight of all ensemble components -- clothing/equipment/ weapons -- far exceeds the soldier's physical capacity for carrying. A look at loads carried reveals another significant area for concern: configurational incompatibilities between the various items, which suggest trouble with respect to the soldier's mobility and portability when he performs in an operational environment. Thus, it is imperative that any newly developed item be considered as only one of a number of components with which the soldier must interact in the performance of his mission.

A third important problem arises when dealing with the combat soldier's response to new items of equipment, viz., the role of his subjective responses in test and evaluation. In fairness to the developer, it should be noted that part of the failure to incorporate troop opinions early in the design process can indirectly be traced to the soldier himself. Characteristically, he has shown little interest in filling out long, cumbersome questionnaires, often couched in a jargon he does not understand, whose relevance to his particular mission and day-to-day functioning is seldom clear. When he does respond, his answers are apt to be superficial, very general in nature, and, as such, provide little specific information upon which to base design changes. Given that the user has worthwhile information to impart, and we strongly believe that he does, the problem becomes one of identifying or developing an opinion/attitude

questionnaire which is short, easy to understand, and requires little effort to administer or complete. It should be noted, however, that even the finest questionnaire in the world is relatively useless unless the information has been collected from individuals performing under conditions which approximate as closely as possible those to be encountered in the operational environment. This brings us to our fourth point, the problem of face validity.

Face validity can be roughly defined as the extent to which a test condition matches or reproduces conditions in the real world. Face validity, as it relates to HFE studies of military clothing and equipment, is extremely important, since it is seldom possible to test items/systems in an actual combat situation. Results from HFE studies must be presented to military personnel who have had a great deal of combat experience, and one of the most frequent objections raised is that the data were collected under conditions which did not approximate closely enough, or were not relevant to, the "real world of combat." To meet such objections is not always easy. Attempts to simulate combat conditions always raise serious questions of cost, personnel, item availability and, most important, the degree of realism seen as necessary.

The final problem to be discussed in this section, the scope of HFE analyses, is one in which the HFE engineer has the least control in resolving. The nature of this problem is basically concerned with the recognition of limitations and constraints which act to limit the scope of HFE evaluations. In our discussion of conceptual problems we have touched upon constraints growing out of requirements for specificity in system definition, the need for subjective evaluations, and the demand for face validity. These constraints, coupled with other limiting factors, impact severely on the magnitude of a given HFE effort and, in turn, on the eventual acceptance of a particular item/system. Regardless of where the HFE inputs are made, whether in early development or advanced testing, the HFE engineer must recognize and live with many limitations in the design features of an item which result from trade-off analyses involving variables and parameters over which he has little or no control.

HFE AND THE PASGT SYSTEM. Having identified some of the more important conceptual problems involved in attempting to "maximize user acceptance," let us return to the research strategy we have used in addressing these questions. To aid in discussion, use will be made of examples from the development of a new Army helmet/vest system designated Personnel Armor System Ground Troops, PASGT.

Figure 1 indicates our general research approach. Items shown in the upper blocks e.g., weight, audition, anthropometrics, etc., actually represent variables which are investigated in what might be termed the "pre-hardware" phase of development. Figure 1 shows a

differential inclusion of variables for the helmet and the vest. One might ask, "Why is the selection of variables different for the two items and, more important, how were the variables themselves selected?" The answer is that, although one can specify in general the type of approach to take in an HFE evaluation, in actual fact every evaluation is "tailor-made;" the nature of the item under development "drives' the selection of variables.

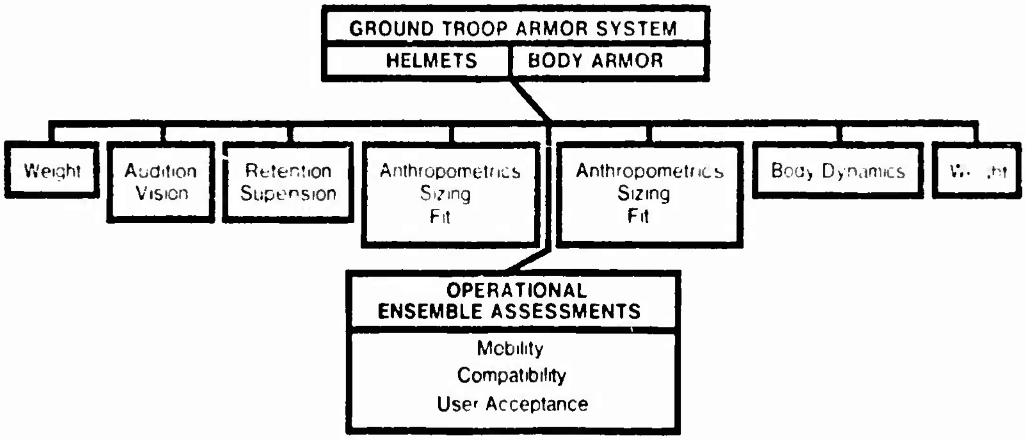


Figure 1. Basic HFE Research Approach

The upper section of Figure 1 also represents the first instance in which we as HFE practitioners must deal with the problem of subjective evaluation as it relates to the measurement of such fundamental human activities as psychomotor performance and perceptual response. Note also, at this point, we are treating the helmet and vest as separate entities, in apparent violation of our own canon to always consider an item as part of a system composed of all other items with which it (the test item) must eventually function. What we are doing at this point can be referred to as a form of "sub-system optimization," an approach in which each item of a system is considered separately in terms of its impact on the human user. Items are then merged into an overall system and examined with respect to the evaluative criteria shown in the lower portion of Figure 1. This section, operational-ensemble assessments, is where we begin to deal with the problems of "total-system" definition, i.e., intra-system component compatibility, and face validity. In addition, it is during the operational assessments that we will once again become involved with the question of subjective evaluations, this time in an attempt to determine how the combat soldier rates all items of the system, after having performed in that system in the operational environment. Let us now illustrate both the selection and application of some HFE

evaluative techniques, as employed in testing the PASGT system.

"PRE-HARDWARE" HFE - PASGT HELMET. Given the requirement for providing design criteria for a new helmet, we began by documenting those features of the standard M1 helmet which had been reported as undesirable (4). A survey of questionnaire responses from Vietnam combat veterans (9) indicated that "too heavy" was the most frequently occurring complaint. We knew that a straight engineering approach to the problem of weight-reduction for helmets and other equipment (the LINCLOE effort) had still resulted in complaints. Our HF engineering approach, therefore, began with an experiment to assess the ability of a soldier to subjectively determine what is heavy and what is light. Unlike the senses of vision and audition, the perception of weight involves no centrally located receptor organs. Weight is sensed through the diffuse series of receptors which signal the central nervous system on the contraction and tension of muscles, as these muscles are recruited to support added weight on the body. Other cues to perceiving weight are provided by sensations of pressure at the points of contact between items worn/carried and the body surface.

The results of this first study (5) indicated that there was a 1.75-pound "range of indecision" for judgments of symmetrically distributed helmet weight, around a 3.0-pound reference weight. Since this conclusion was reached using subjects in a static situation with symmetric weight distributions, we next looked at the effects of asymmetric loadings on the ability of subjects to perceive weight on the head. Findings from this study indicated that the soldier is much more sensitive to asymmetric weight; indeed, he can determine imbalances as small as one-quarter pound (8). This, and other studies convinced us that "pure weight" was not the primary problem.

When a soldier wears his helmet in a static condition, his musculature supports only the weight generated by the forces of gravity. However, when he moves as a soldier must, additional forces are generated. Inertial forces tend to cause the helmet to lag behind head movements. When the helmet "catches" the head, momentum tends to keep the helmet moving. When the helmet stops, forces continue to be exerted on the head for some undetermined length of time. The human body is not equipped with inertial or momentum receptors, so these forces are reported as weight. Therefore, it was reasonable to conclude that some portion of perceived helmet weight must be attributed to forces other than those of absolute physical weight.

In 1958 Lewis et al. (6) studied the relationship between weight, ballistic protection and rotational forces as a function of helmet stand-off (the distance between the head and the interior surface of the helmet). Their findings indicated that, as stand-off increased, the amount of total ballistic surface area coverage of the head remains the same although the total helmet weight increases. They

concluded that "it is imperative, therefore, that the radius of the shell ($r_s$) is nearly equal to the radius of the head ($r_h$) as possible." From these observations, it was apparent to us that stand-off and shape were of considerable importance to the total perception of helmet weight. Since factors such as stand-off and helmet-shell thickness were primarily keyed to ballistics, casualty reduction and material properties -- factors not yet resolved in the development of the new helmet -- it became obvious that the most productive place for HFE efforts at this time was in shape considerations.

The shape of a new helmet, we felt, was extremely important for eventual user acceptance, for a number of reasons unrelated to ballistics per se. In the soldier's combat clothing/equipment ensemble, the helmet is actually the only readily identified, separate item. As such, it tends to become associated with, and to some extent defines, the image of the "American Fighting Man." This is particularly true of an item such as the current M1 helmet which has become familiar to three generations of Americans. Thus, no matter how many complaints are made about it, such an embedded item is bound to resist displacement to some extent. Conversely, an item representing or evocative of past or present "enemies" has acquired negative connotations, and any new/replacement design risks rejection to the extent to which it is perceived as being similar to the enemy equipment. With this in mind, we performed an experiment to see if it was possible to survey the esthetic qualities of a military helmet (3). One hundred enlisted infantrymen served as subjects. They were presented with eight sketches of present and "futuristic" helmet designs shown in Figure 2. With the exception of number 70, the Hayes-Stewart

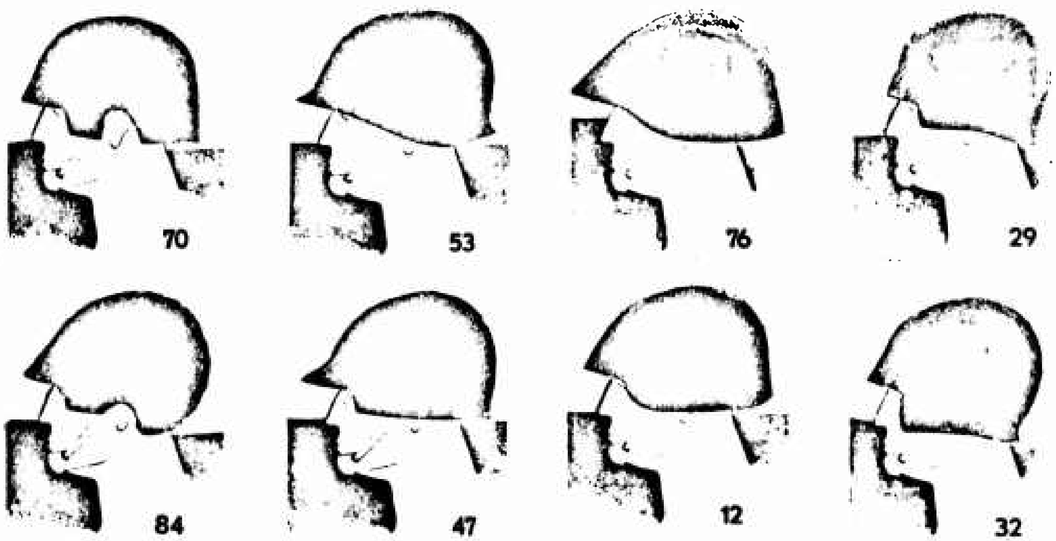


Figure 2. Candidates In Helmet Esthetics Survey

helmet, and number 53, the M1 itself, all helmet shapes were actually variations around the basic M1 shell i.e., variations in edge cut and configuration of the standard item. As explained to the subjects, the purpose of the study was to aid in selecting a new Army helmet for "ceremonial" purposes; this was done in an effort to have the subjects judge the helmets solely on the basis of esthetic merit, and not on the grounds of ballistic protection and/or utility. Subjects were asked to choose the helmet configuration they judged as "best looking," their "second-best" choice, and the configuration they thought looked "worst." The results were not surprising. Combining first and second choices, 66% of the sample selected #53, the M1, as most desirable. Helmet #12 was the second overall choice, with a combined total of 46%. When we considered that the basic shape and edge cut of #12 satisfied many of the Surgeon General's requirements for increased coverage/protection below the Frankfort plane, we adopted it as a provisional candidate upon which to base design recommendations. We were reasonably confident in our choice, since we also suspected the #12, with its increased head coverage, would have a lower center of gravity, one closer to that of the head. Basic physics told us that the lower (and closer) the head and helmet cg's, the smaller the rotary moments of inertia and, hence, the less inertial force present to generate reports of "too heavy" or "unstable." That we were correct in our assumptions is borne but by the data shown in Table 1, obtained when prototype helmets became available.

TABLE 1. HELMET MOMENTS OF INERTIA (LB. IN.$^2$) ABOUT THE CG OF THE HELMET AND CG OF THE HEAD

| | | | AXIS | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | YAW | | ROLL | | PITCH | |
| HELMET | SIZE | WGT (oz) | HELMET | HEAD | HELMET | HEAD | HELMET | HEAD |
| M1 | MED. | 54 | 48.0 | 50.0 | 33.5 | 55.5 | 38.0 | 62.9 |
| PASGT (38 oz.) | SML | 47 | 39.1 | 46.0 | 27.8 | 40.6 | 28.7 | 41.1 |
| | MED. | 49 | 43.6 | 46.7 | 30.6 | 49.7 | 32.4 | 44.2 |
| | LRG. | 53 | 50.0 | 53.1 | 35.2 | 63.2 | 37.0 | 58.9 |

HFE EARLY EVALUATION OF PROTOTYPE ITEMS. Early development testing begins with the availability of prototype items. We must now evaluate

the effectiveness of previous HFE recommendations as modified by trade-offs involving materiel characteristics, manufacturing techniques, ballistics, etc. The infantryman and his rifle form a weapons system which must be an efficient combination on the battlefield. As in any system, restrictions on any one component may influence total system effectiveness. Hence, any piece of equipment such as a helmet or armor vest may restrict the soldier in the act of firing and thus interfere with system performance. Two anticipated effects of the rifleman/equipment interface involve a) the individual's ability to hit the target while equipped with body armor, and b) the effect of armor on his time to fire. To investigate these effects we designed and constructed an automated pop-up target range which provides time to fire and hit/miss data for each target engaged, as well as high-speed film coverage of the firing position.

While it is important to determine the degree to which a soldier and his weapon, as a system, can produce rapid and accurate fire from a relatively static position, it is equally important to determine how well the soldier and his equipment interact in a dynamic environment.

To answer the need for a facility which allows testing under conditions approximating those expected to obtain in combat, we have developed a Human Engineering Laboratory (HEL) mobility/portability test course (M/P). The history of the present course began with a series of studies by Dunlap and Associates (2) at the request of the Army's General Equipment Test Activity, Fort Lee, VA. The aim of these studies was to develop methodology for measuring the effects of personal clothing/equipment on the combat effectiveness of individual soldiers. Based on lengthy evaluations of performance requirements solicited from combat veterans covering three wars, these studies culminated in the design and construction of the combat effectiveness test course (CETC). Upon its untimely demise, we selected one of the nine original CETC courses, the maneuver course, as a model for the construction of our own facility. Our course is designed to subject each man to those kinds of circumstances that would be encountered in a variety of fighting situations, so we can measure his ability to perform infantry-relevant tasks such as running, jumping, swinging, balancing, vaulting and crawling. Thirteen obstacles are used to reveal incompatibilities between the soldier's clothing/equipment as he negotiates the course. The course also contains obstacles requiring skills which might be demanded in city fighting (MOBA) situations e.g., doorways, stairways, alleys, sewer pipe crawls, etc.

Once the soldier has experienced situations requiring him to perform a set of combat-relevant tasks, it is crucial to obtain his attitude toward the item/system being tested as quickly as possible. This brings us to the development and selection of the semantic differential.

After a literature review and a number of pilot studies, we

selected the Osgood's semantic differential (SD) as our basic opinion/ rating scale. As shown in Figure 3, the SD involves the use of bipolar adjective pairs, the adjectives of each pair forming the end points of a seven-point scale. Certain statistical analyses e.g., factor analysis, may be subsequently used to minimize the number of adjective pairs in the final questionnaire. Advantages of this technique include amenability to statistical analysis, the ability to be tailored (via word-association tests) to specific educational levels,

| | Extreme | Moderate | Slight | Neutral | Slight | Moderate | Extreme | |
|---|---|---|---|---|---|---|---|---|
| Slips | 0 | 0 | 0 | 0 | 0 | 0 | 0 | Clings |

Figure 3. Semantic Differential

and the capacity to be quickly represented in graph or profile format. In the development of our particular rating scales for items such as helmets and vests, we have departed somewhat from Osgood's original use of adjectives only. We did this because we found it difficult, if not impossible, to elicit opinions regarding the dynamic behavior of an item without including verbs or occasionally adverbs as end points on the scale.

<u>HFE IN EARLY PASGT TESTING</u>. Our analysis and comparison of the PASGT and Standard Helmet/Body Armor Systems is described in great detail elsewhere (1,10). Basically, the systems were compared by means of six procedures. First, after classifying the systems with respect to physical characteristics and design features, we made anthropometric measurements of the subjects to perform in the test, and each system was assessed as to the adequacy of fit for selected environmental clothing ensembles and assault load-carrying ensembles. Next, "static" measurements were made to determine the movement characteristics of each system on the body of the wearer. Compatibility assessments were then conducted using a variety of infantry-operated systems and equipment ranging from shoulder-launched rockets, communications equipment, and crew-served weapons, to night-vision sights and goggles. As a result of these compatibility assessments, a recommendation was made to increase the helmet-face opening to accommodate field use of communication equipment.

After the "static" assessments were completed, the systems were tested using the techniques previously detailed. Weapon-firing

behavior was examined by having the subjects fire while wearing each of the systems in conjunction with load-bearing equipment and various environmental clothing ensembles. Mobility/portability was assessed by having each subject wear each of the systems plus an assault load and various environmental clothing ensembles while negotiating the M/P course. To determine the extent to which differences between the systems were apparent to the subjects, the semantic differential was administered after each M/P course run.

Objective performance measures, as well as photographic data, were accumulated for both the rifle firing and M/P course runs. Analyses of the objective data indicated that no significant differences existed between the systems for either rifle firing or M/P course runs. For instance, mean obstacle times for running the M/P course ranged from 10.885 to 11.421 seconds. However, observations by test personnel and analysis of photographic data revealed some areas of potential difference between the systems. During rifle firing it was noted that the vest collar made contact with the rear edge of the helmet and, in certain firing attitudes, caused the helmet to rotate forward. This helmet/vest interaction was further investigated by

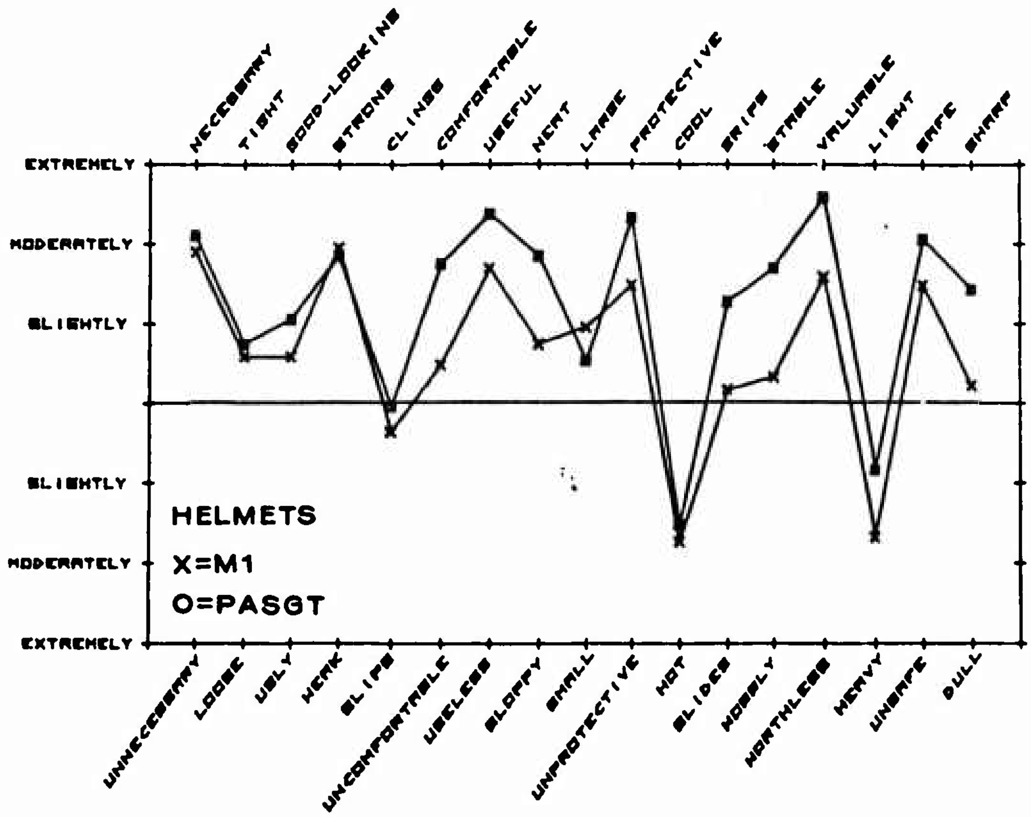


Figure 4. Semantic Profiles -- Standard M1 vs. PASGT Helmet

having subjects fire without wearing a helmet. Results showed a statistically significant improvement in firing accuracy in the without-helmet condition. This change in performance coupled with previous observations resulted in a recommendation to reduce the rear-edge cut of the helmet and eliminate the collar of the vest.

Stability-related differences between the standard and PASGT design system were noted during M/P course negotiation. These differences were confirmed when results of the semantic differential were analyzed. Figure 4 depicts the results of an M1 vs. PASGT helmet comparison.

Figure 5 shows the results of the standard vs. PASGT design vest comparison.

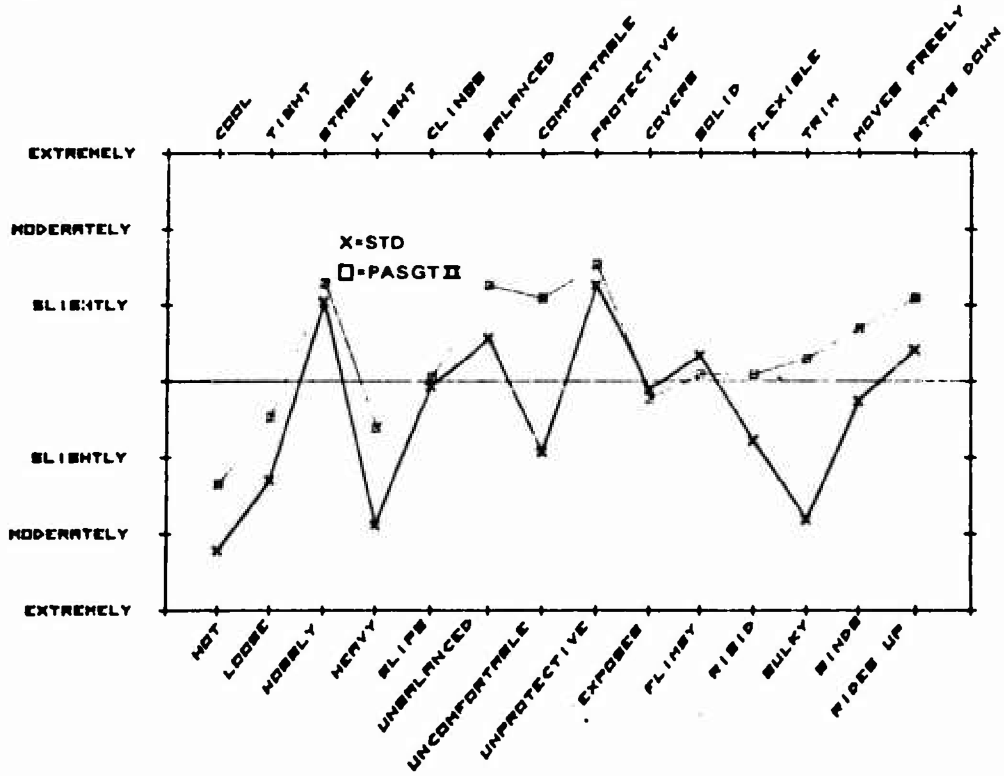


Figure 5. Semantic Profiles -- Standard B vs. PASGT Armored Vest

It can readily be seen that the PASGT design helmet received more favorable ratings across all stability and comfort-related areas. In particular, the PASGT helmet was rated lighter than the standard, even though both weighed approximately the same. This result was in consonance with previous findings.

The same general observation can be made for the PASGT vest,

which was rated more favorably than the standard across the dimensions employed in this rating scale.

The semantic differential data were further analyzed to ascertain reliability, particularly over time. Data obtained on the standard M1 helmet from a group of AIT graduates was compared to that obtained from a group of soldiers from the 82nd Airborne Division. There was about a nine-month time lapse between when the two groups were surveyed, as well as the fact that the AIT group wore temperate zone uniforms, while the 82nd Airborne Division group wore standard arctic-clothing ensembles. The results of this comparison are shown in Figure 6.

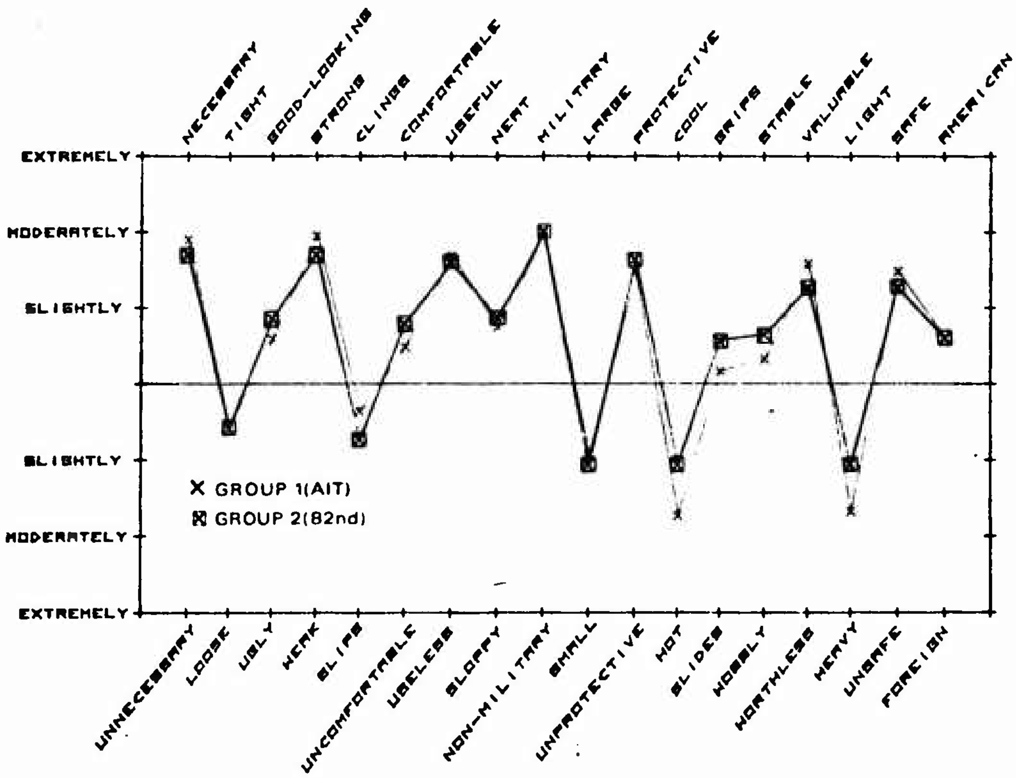


Figure 6. Semantic Profiles -- Reliability of M1 Ratings

Little or no difference exists in the mean ratings of these two highly divergent groups, thus attesting to the reliability of the semantic differential.

FUTURE HFE. We mentioned the lack of statistically significant differences on the objective performance measures for the systems compared during the PASGT program. One reason for this is that the subjects participating in our evaluation had not been sufficiently

stressed to have elicited a discernable change in performance. Subjects had not been exposed to stress encounterable in combat -- such as sleep deprivation, environmental stress, field diet, and emotional stress. Our system evaluations are now being structured within the context of an extended field exercise that will attempt to simulate some of these conditions.

The sensitivity of our measurement instruments is such that times to accomplish activities are recorded down to one-thousandth of a second. Even when there are statistically significant differences obtained during rifle firing and/or M/P course runs, they may or may not be operationally significant. "How much of a difference, is a difference?," is a question we continually ask ourselves and the user. Any system change that decreases task-accomplishment time is obviously beneficial; however, in our age of cost awareness, the question now becomes "Is the change in performance cost-effective?"

In terms of future directions for methodological improvement, study is ongoing to identify operational scenarios incorporating meaningful task-execution times. Individual performance as now measured is insufficient, in that activities engaged in during combat operations are not individually isolated, but are part of some group effort. Work is directed toward identifying suitable techniques to measure group performance in a dynamic environment with sufficient sensitivity to measure the variations in individual performance within the group context.

Lastly, a scheme for assigning weights to the evaluative techniques in terms of their contribution to assessing operational and functional suitability as well as user acceptance of an item is being sought.

The answers to these and other problems lie in future research. However, let us conclude by saying that, regardless of the specific techniques and methodologies which may evolve, we will continue to base our overall HFE approach on the following guidelines:

1. Work as closely as possible with the user representatives to obtain agreed-upon mission scenarios, task analyses, clothing/equipment ensembles, etc.

2. Where possible, develop controllable "mini-environments" which require "generic" types of performance that correlate well with known combat-derived or doctrinal performance requirements.

3. Try to insure that testing takes place across the spectrum of environmental conditions under which the combat-soldier-as-a-system will be expected to perform.

4. Select as test subjects individuals who by virtue of MOS, training, ability, physical condition, anthropometrics and experience are representative of the population of eventual users.

5. Consider the item under development as only one of a number of components which make up the combat infantry system -- the soldier,

his weapon, uniform, environmental ensemble, LBE, vehicle and other ancillary equipment.

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